

Waste Isolation Pilot Plant 2001 Site Environmental Report
DOE/WIPP 02-2225

Strontium-90 was only detected at WEE, depth 0-2cm, slightly above the MDC (Table 4.13). However, ^{60}Co was not detected in any of the soil samples. There was nonsignificant difference in ^{60}Co concentrations between years ($p = 0.421$).

Soil samples collected from one location (WEE) were divided into two parts and analyzed separately (Table 4.14). Uranium-234, ^{238}U , ^{40}K , and ^{137}Cs were compared between the duplicates. Other radionuclides of interest had insufficient detections to allow a reasonable comparison. The RER was greater than one for ^{234}U and ^{238}U in all samples. However, it was less than one in one for ^{40}K analyses and ^{137}Cs analyses. A paired t-test indicated no significant difference between ^{234}U duplicates ($p = 0.624$) and between ^{238}U duplicates ($p = 0.666$). This circumstance indicates a lack of precision in these analyses, primarily due to the non-homogeneous distribution of radionuclides in soils. Because of small-scale differences in topography, soil type and structure, soil moisture, and other microenvironmental conditions, radionuclides are rarely homogeneously distributed in soils, and good agreement between duplicate samples is difficult to achieve. However, all the measurements were low, within the range of natural concentrations, and did not differ in time or space in such a way as to suggest WIPP-related contamination of the environment.

Table 4.14 - Results of Duplicate Soil Sample Analysis. Units are Bq/g.
See Appendix B for the sampling locations.

Location	Depth (cm)	[RN] ^a	2×TPU ^b	MDC ^c	RER ^d	[RN]	2×TPU ^a	MDC ^b	RER ^c
		^{234}U				^{238}U			
WEE	0-2	5.66×10^{-3}	1.35×10^{-3}	1.02×10^{-4}	2.94	6.85×10^{-3}	1.57×10^{-3}	1.01×10^{-4}	2.26
WEE D ^e	0-2	1.50×10^{-2}	2.88×10^{-3}	8.92×10^{-4}		1.39×10^{-2}	2.70×10^{-3}	8.88×10^{-5}	
WEE	2-5	6.73×10^{-3}	1.38×10^{-3}	7.81×10^{-5}	2.63	7.33×10^{-3}	1.48×10^{-3}	7.77×10^{-5}	2.81
WEE D ^e	2-5	1.57×10^{-2}	3.12×10^{-3}	9.99×10^{-5}		1.81×10^{-2}	3.53×10^{-3}	9.92×10^{-5}	
WEE	5-10	1.84×10^{-2}	3.68×10^{-3}	2.83×10^{-4}	1.94	2.00×10^{-2}	3.96×10^{-3}	1.04×10^{-4}	1.90
WEE D ^e	5-10	1.01×10^{-2}	2.20×10^{-3}	3.00×10^{-4}		1.12×10^{-2}	2.39×10^{-3}	3.77×10^{-4}	
		^{40}K				^{137}Cs			
		[RN]	2×TPU	MDC	RER	[RN]	2×TPU	MDC	RER
WEE	0-2	2.25×10^{-1}	3.07×10^{-2}	7.36×10^{-3}	0.40	2.21×10^{-3}	5.48×10^{-4}	6.55×10^{-4}	0.25
WEE D ^e	0-2	2.43×10^{-1}	3.30×10^{-2}	6.29×10^{-3}		2.40×10^{-3}	5.22×10^{-4}	5.55×10^{-4}	
WEE	2-5	2.62×10^{-1}	3.55×10^{-2}	1.32×10^{-2}	0.41	2.49×10^{-3}	6.22×10^{-4}	7.62×10^{-4}	0.18
WEE D ^e	2-5	2.42×10^{-1}	3.28×10^{-2}	6.36×10^{-3}		2.35×10^{-3}	4.74×10^{-4}	4.55×10^{-4}	
WEE	5-10	2.62×10^{-1}	3.55×10^{-2}	1.32×10^{-2}	0.22	2.49×10^{-3}	6.22×10^{-4}	7.62×10^{-4}	0.50
WEE D ^e	5-10	2.51×10^{-1}	3.42×10^{-2}	1.34×10^{-2}		2.12×10^{-3}	4.07×10^{-4}	5.14×10^{-4}	

^a [RN] = Radionuclide concentration

^b Total propagated uncertainty

^c Minimum detectable concentration

^d Relative Error Ratio

^e Duplicate

4.7 Sediments

4.7.1 Sample Collection

Sediment samples were collected from 12 locations around the WIPP site, mostly from the same water bodies from which the surface water samples were collected (Figure 4.7, see Appendix B for location codes). The samples were collected in 1 l

plastic containers from the top 15 cm (6 in) of the sediments of the water bodies and shipped to the laboratory for the determination of individual radionuclides.

4.7.2 Sample Preparation

Sediment samples were dried at 110°C (230°F) for several hours and homogenized by grinding to smaller particle sizes. A 0.75-g (0.04-oz) aliquot was dissolved by heating it with a mixture of nitric, hydrochloric, and hydrofluoric acids. The residue was heated with nitric and boric acids to remove hydrofluoric acid quantitatively. Finally, the residue was dissolved in hydrochloric acid for the determination of individual radionuclides.

4.7.3 Determination of Individual Radionuclides

About 100 g (4 oz) of dried and homogenized sediment samples were counted by gamma-spectrometry for the determinations of ^{40}K , ^{60}Co , and ^{137}Cs . Strontium-90 was determined from an aliquot of dissolved sediment samples by chemical separation and beta counting. Uranium, plutonium, and americium were determined by alpha spectrometry after chemical separations, micro-precipitating, and filtering onto micro filter papers.

4.7.4 Results and Discussions

Uranium-234, ^{235}U , and ^{238}U were detected in every sediment sample in (Table 4.15). The concentration of ^{234}U ranged from $1.73 \times 10^{-2} \pm 3.10 \times 10^{-3}$ Bq/g ($4.68 \times 10^{-1} \pm 8.38 \times 10^{-2}$ pCi/g) at LST to $4.96 \times 10^{-2} \pm 8.33 \times 10^{-3}$ Bq/g ($1.34 \times 10^0 \pm 2.25 \times 10^{-1}$ pCi/g) at CBD. The concentration of ^{235}U ranged from $9.32 \times 10^{-4} \pm 3.60 \times 10^{-4}$ Bq/g ($2.52 \times 10^{-2} \pm 9.73 \times 10^{-3}$ pCi/g) at RED to $2.12 \times 10^{-3} \pm 6.25 \times 10^{-4}$ Bq/g ($5.73 \times 10^{-2} \pm 1.69 \times 10^{-2}$ pCi/g) at CBD. The concentration of ^{238}U was lowest at LST ($1.84 \times 10^{-2} \pm 3.27 \times 10^{-3}$ Bq/g [$4.97 \times 10^{-1} \pm 8.84 \times 10^{-2}$ pCi/g]) and highest at CBD ($3.35 \times 10^{-2} \pm 5.74 \times 10^{-4}$ Bq/g [$9.05 \times 10^{-1} \pm 1.55 \times 10^{-2}$ pCi/g]). As expected, the ^{235}U concentration was much lower than the concentrations of ^{234}U and ^{238}U . There was not a significant difference between sampling years (ANOVA ^{234}U p = 0.526, ^{235}U p = 0.399, ^{238}U p = 0.315).

Plutonium-238 was not detected in any sediment sample in 2001 (Table 4.16). Americium-241 was measured above the MDC at BRA. Plutonium-239+240 concentration was greater than the MDC at BRA, IDN, and Poker Trap [PKT]. These samples were processed several times in the laboratory due to interference in the spectra. The samples showed concentration barely above the MDC for two out of three analysis. The apparent lack of homogeneity of the samples caused the different results. Sample location BRA indicated ^{241}Am concentration above the MDC. This sample was also reprocessed for spectral interference. The radionuclide concentrations in Table 4.16 are the reprocessed results.

Cesium-137 was detected in all the sediment samples, ranging from $4.14 \times 10^{-4} \pm 1.60 \times 10^{-4}$ Bq/g ($1.12 \times 10^{-2} \pm 4.32 \times 10^{-3}$ pCi/g) at UPR to $4.59 \times 10^{-2} \pm 5.77 \times 10^{-3}$ Bq/g ($1.24 \times 10^0 \pm 1.56 \times 10^{-1}$ pCi/g) at BRA (Table 4.17). Cesium-137 did not differ statistically between sampling years 2000 and 2001 (ANOVA p = 0.397).

Waste Isolation Pilot Plant 2001 Site Environmental Report
DOE/WIPP 02-2225

Strontium-90 was not detected in any sediment samples and Cobalt-60 was detected in one sediment sample (BRA). None of these radionuclides had sufficient detections to justify statistical comparisons between locations or years.

Potassium-40 was detected, as expected, in all sediment samples (Table 4.17). Its lowest concentration was found at CBD ($2.49 \times 10^{-1} \pm 3.25 \times 10^{-2}$ Bq/g [$6.73 \times 10^0 \pm 8.78 \times 10^{-1}$ pCi/g]) and its highest concentration was found at TUT ($1.04 \times 10^0 \pm 1.34 \times 10^{-1}$ Bq/g [$2.81 \times 10^1 \pm 3.62 \times 10^{-1}$ pCi/g]). Potassium-40 did not vary significantly between years (ANOVA, $p = 0.977$). Overall, the concentrations measured in 2001 were similar to the average concentration of ^{40}K found in soils throughout the United States (4.00×10^{-1} Bq/g [1.08×10^1 pCi/g]; NCRP, 1994).

Duplicate analyses were performed for all the radionuclides in sediment samples IDN and TUT (Table 4.18). The RER was less than one for ^{241}Am and all uranium isotopes, indicating acceptable correspondence between the original and the duplicate samples. For ^{137}Cs and ^{40}K , it was greater than one for location TUT. However, a t-test indicated no significant difference between any of these duplicate measurements for ^{40}K ($p = 0.613$) and ^{137}Cs ($p = 0.723$).

Table 4.15 - Uranium Concentrations (Bq/g) in Sediment Near the WIPP Site.
See Appendix B for the sampling locations.

Location	^{234}U			^{235}U			^{238}U		
	[RN] ^a	2 × TPU ^b	MDC ^c	[RN]	2 × TPU	MDC	[RN]	2 × TPU	MDC
BRA	2.82×10^{-2}	4.81×10^{-3}	6.25×10^{-5}	1.51×10^{-3}	4.81×10^{-4}	7.73×10^{-5}	2.61×10^{-2}	4.48×10^{-3}	6.25×10^{-5}
BHT	2.15×10^{-2}	3.67×10^{-3}	5.99×10^{-5}	1.25×10^{-3}	4.18×10^{-4}	7.40×10^{-5}	2.32×10^{-2}	3.96×10^{-3}	1.62×10^{-4}
CBD	4.96×10^{-2}	8.33×10^{-3}	7.07×10^{-5}	2.12×10^{-3}	6.25×10^{-4}	8.70×10^{-5}	3.35×10^{-2}	5.74×10^{-3}	1.91×10^{-4}
HIL	1.92×10^{-2}	3.51×10^{-3}	7.18×10^{-5}	1.50×10^{-3}	5.11×10^{-4}	8.84×10^{-5}	2.09×10^{-2}	3.77×10^{-3}	1.94×10^{-4}
IDN	2.33×10^{-2}	3.89×10^{-3}	5.40×10^{-5}	1.23×10^{-3}	4.03×10^{-4}	1.81×10^{-4}	2.30×10^{-2}	3.85×10^{-3}	5.37×10^{-5}
LST	1.73×10^{-2}	3.10×10^{-3}	2.21×10^{-4}	1.15×10^{-3}	4.11×10^{-4}	7.96×10^{-5}	1.84×10^{-2}	3.27×10^{-3}	6.44×10^{-5}
NOY	2.32×10^{-2}	3.89×10^{-3}	5.81×10^{-5}	1.21×10^{-3}	4.07×10^{-4}	7.14×10^{-5}	2.43×10^{-2}	4.07×10^{-3}	5.77×10^{-5}
PCN	3.56×10^{-2}	6.29×10^{-3}	2.00×10^{-4}	1.91×10^{-3}	5.99×10^{-4}	9.07×10^{-5}	3.20×10^{-2}	5.66×10^{-3}	7.33×10^{-5}
PKT	2.55×10^{-2}	4.18×10^{-3}	1.53×10^{-4}	1.94×10^{-3}	5.37×10^{-4}	6.92×10^{-5}	2.70×10^{-2}	4.40×10^{-3}	5.59×10^{-5}
RED	1.94×10^{-2}	3.34×10^{-3}	1.74×10^{-4}	9.32×10^{-4}	3.60×10^{-4}	7.88×10^{-5}	1.92×10^{-2}	3.30×10^{-3}	6.36×10^{-5}
TUT	2.32×10^{-2}	3.89×10^{-3}	6.62×10^{-5}	1.63×10^{-3}	5.07×10^{-4}	8.18×10^{-5}	2.53×10^{-2}	4.18×10^{-3}	6.59×10^{-5}
UPR	2.60×10^{-2}	4.48×10^{-3}	6.40×10^{-5}	1.31×10^{-3}	4.51×10^{-4}	2.15×10^{-4}	2.69×10^{-2}	4.63×10^{-3}	6.36×10^{-5}

^a [RN] = Radionuclide concentration

^b Total propagated uncertainty

^c Minimum detectable concentration

Waste Isolation Pilot Plant 2001 Site Environmental Report
DOE/WIPP 02-2225

Table 4.16 - Americium and Plutonium Concentrations (Bq/g) in Sediment Near the WIPP Site.
See Appendix B for the sampling locations.

Location	[RN] ^a	2 × TPU ^b	MDC ^c	[RN]	2 × TPU	MDC	[RN]	2 × TPU	MDC
	²⁴¹ Am			²³⁸ Pu			²³⁹⁺²⁴⁰ Pu		
BRA	7.10×10 ⁻⁴	4.03×10 ⁻⁴	1.37×10 ⁻⁴	1.23×10 ⁻⁴	1.25×10 ⁻⁴	8.33×10 ⁻⁵	2.46×10 ⁻³	6.85×10 ⁻⁴	8.33×10 ⁻⁵
BHT	2.04×10 ⁻⁴	2.18×10 ⁻⁴	3.16×10 ⁻⁴	0.00×10 ⁰	0.00×10 ⁰	3.03×10 ⁻⁴	1.64×10 ⁻⁴	1.67×10 ⁻⁴	1.11×10 ⁻⁴
CBD	3.06×10 ⁻⁵	1.37×10 ⁻⁴	2.84×10 ⁻⁴	1.02×10 ⁻⁴	1.04×10 ⁻⁴	6.96×10 ⁻⁵	7.70×10 ⁻⁵	8.95×10 ⁻⁵	6.96×10 ⁻⁵
HIL	1.51×10 ⁻⁴	1.62×10 ⁻⁴	2.22×10 ⁻⁴	-8.14×10 ⁻⁵	1.16×10 ⁻⁴	3.77×10 ⁻⁴	1.62×10 ⁻⁴	1.65×10 ⁻⁴	1.10×10 ⁻⁴
IDN	0.00×10 ⁰	0.00×10 ⁰	2.30×10 ⁻⁴	-3.96×10 ⁻⁵	1.38×10 ⁻⁴	3.68×10 ⁻⁴	7.92×10 ⁻⁴	3.85×10 ⁻⁴	1.07×10 ⁻⁴
LST	1.10×10 ⁻⁴	1.57×10 ⁻⁴	2.55×10 ⁻⁴	6.85×10 ⁻⁵	1.37×10 ⁻⁴	2.51×10 ⁻⁴	1.36×10 ⁻⁴	1.38×10 ⁻⁴	9.25×10 ⁻⁵
NOY	1.43×10 ⁻⁴	1.74×10 ⁻⁴	2.66×10 ⁻⁴	3.89×10 ⁻⁵	1.35×10 ⁻⁴	2.87×10 ⁻⁴	1.95×10 ⁻⁴	2.08×10 ⁻⁴	2.87×10 ⁻⁴
PCN	0.00×10 ⁰	0.00×10 ⁰	2.19×10 ⁻⁴	0.00×10 ⁰	0.00×10 ⁰	5.03×10 ⁻⁴	0.00×10 ⁰	0.00×10 ⁰	1.47×10 ⁻⁴
PKT	7.73×10 ⁻⁵	1.10×10 ⁻⁴	1.05×10 ⁻⁴	7.88×10 ⁻⁵	1.58×10 ⁻⁴	2.90×10 ⁻⁴	7.07×10 ⁻⁴	3.74×10 ⁻⁴	2.90×10 ⁻⁴
RED	8.25×10 ⁻⁵	1.24×10 ⁻⁴	2.02×10 ⁻⁴	7.77×10 ⁻⁵	1.16×10 ⁻⁴	1.90×10 ⁻⁴	7.73×10 ⁻⁵	9.03×10 ⁻⁵	6.99×10 ⁻⁵
TUT	3.05×10 ⁻⁵	1.06×10 ⁻⁴	2.25×10 ⁻⁴	-2.51×10 ⁻⁵	5.03×10 ⁻⁵	1.85×10 ⁻⁴	1.25×10 ⁻⁴	1.34×10 ⁻⁴	1.85×10 ⁻⁴
UPR	0.00×10 ⁰	0.00×10 ⁰	7.10×10 ⁻⁵	-5.22×10 ⁻⁵	1.05×10 ⁻⁴	2.81×10 ⁻⁴	7.81×10 ⁻⁵	9.10×10 ⁻⁵	7.07×10 ⁻⁵

^a [RN] = Radionuclide concentration

^b Total propagated uncertainty

^c Minimum detectable concentration

Waste Isolation Pilot Plant 2001 Site Environmental Report
DOE/WIPP 02-2225

Table 4.17 - Selected Radionuclide Concentrations (Bq/g) in Sediment Near the WIPP Site.
See Appendix B for the sampling locations.

Location	[RN] ^a	2 × TPU ^b	MDC ^c	[RN]	2 × TPU	MDC
	¹³⁷ Cs			⁶⁰ Co		
BRA	4.59×10 ⁻²	5.77×10 ⁻³	4.22×10 ⁻⁴	6.85×10 ⁻⁴	5.85×10 ⁻⁴	6.73×10 ⁻⁴
BHT	6.77×10 ⁻³	9.03×10 ⁻⁴	3.58×10 ⁻⁴	4.14×10 ⁻⁵	5.88×10 ⁻⁴	6.59×10 ⁻⁴
CBD	2.51×10 ⁻³	4.74×10 ⁻⁴	4.77×10 ⁻⁴	2.60×10 ⁻⁴	5.07×10 ⁻⁴	5.85×10 ⁻⁴
HIL	7.99×10 ⁻³	1.10×10 ⁻³	5.14×10 ⁻⁴	8.40×10 ⁻⁵	6.25×10 ⁻⁴	7.10×10 ⁻⁴
IDN	5.85×10 ⁻³	7.84×10 ⁻⁴	3.36×10 ⁻⁴	-1.18×10 ⁻⁴	2.50×10 ⁻⁴	2.74×10 ⁻⁴
LST	1.73×10 ⁻³	4.14×10 ⁻⁴	5.11×10 ⁻⁴	5.40×10 ⁻⁴	5.07×10 ⁻⁴	5.88×10 ⁻⁴
NOY	8.92×10 ⁻⁴	2.64×10 ⁻⁴	3.47×10 ⁻⁴	2.36×10 ⁻⁴	4.85×10 ⁻⁴	5.55×10 ⁻⁴
PCN	7.62×10 ⁻⁴	1.69×10 ⁻⁴	2.55×10 ⁻⁴	1.55×10 ⁻⁴	4.51×10 ⁻⁴	5.18×10 ⁻⁴
PKT	1.61×10 ⁻²	2.03×10 ⁻³	4.26×10 ⁻⁴	3.42×10 ⁻⁴	7.07×10 ⁻⁴	7.99×10 ⁻⁴
RED	4.07×10 ⁻³	5.77×10 ⁻⁴	3.70×10 ⁻⁴	5.00×10 ⁻⁴	5.48×10 ⁻⁴	6.33×10 ⁻⁴
TUT	3.81×10 ⁻³	5.62×10 ⁻⁴	4.44×10 ⁻⁴	3.81×10 ⁻⁴	7.29×10 ⁻⁴	8.25×10 ⁻⁴
UPR	4.14×10 ⁻⁴	1.60×10 ⁻⁴	3.57×10 ⁻⁴	5.37×10 ⁻⁴	5.33×10 ⁻⁴	6.18×10 ⁻⁴
Location	⁹⁰ Sr			⁴⁰ K		
BRA	1.70×10 ⁻²	1.55×10 ⁻²	2.49×10 ⁻²	5.51×10 ⁻¹	7.10×10 ⁻²	6.51×10 ⁻³
BHT	1.45×10 ⁻²	1.16×10 ⁻²	1.80×10 ⁻²	6.66×10 ⁻¹	8.55×10 ⁻²	5.96×10 ⁻³
CBD	1.79×10 ⁻³	6.59×10 ⁻³	1.11×10 ⁻²	2.49×10 ⁻¹	3.25×10 ⁻²	5.59×10 ⁻³
HIL	6.85×10 ⁻³	7.59×10 ⁻³	1.20×10 ⁻²	8.66×10 ⁻¹	1.11×10 ⁻¹	6.55×10 ⁻³
IDN	-5.48×10 ⁻⁴	8.03×10 ⁻³	1.35×10 ⁻²	4.81×10 ⁻¹	6.18×10 ⁻²	6.07×10 ⁻³
LST	-3.07×10 ⁻³	6.44×10 ⁻³	1.10×10 ⁻²	3.89×10 ⁻¹	5.03×10 ⁻²	6.03×10 ⁻³
NOY	-7.22×10 ⁻⁴	6.07×10 ⁻³	1.02×10 ⁻²	4.77×10 ⁻¹	6.18×10 ⁻²	6.25×10 ⁻³
PCN	1.54×10 ⁻³	6.66×10 ⁻³	1.10×10 ⁻²	3.27×10 ⁻¹	4.26×10 ⁻²	5.33×10 ⁻³
PKT	2.16×10 ⁻³	7.07×10 ⁻³	1.16×10 ⁻²	8.70×10 ⁻¹	1.10×10 ⁻¹	6.99×10 ⁻³
RED	1.32×10 ⁻³	6.92×10 ⁻³	1.15×10 ⁻²	4.85×10 ⁻¹	6.25×10 ⁻²	6.18×10 ⁻³
TUT	2.52×10 ⁻³	7.14×10 ⁻³	1.20×10 ⁻²	1.04×10 ⁰	1.34×10 ⁻¹	7.77×10 ⁻³
UPR	-2.64×10 ⁻⁴	6.99×10 ⁻³	1.20×10 ⁻²	4.81×10 ⁻¹	6.22×10 ⁻²	6.07×10 ⁻³

^a [RN] = Radionuclide concentration

^b Total propagated uncertainty

^c Minimum detectable concentration

Waste Isolation Pilot Plant 2001 Site Environmental Report

DOE/WIPP 02-2225

Table 4.18 - Results of Duplicate Sediment Sample Analysis. Units are Bq/g.
See Appendix B for the sampling locations.

	[RN] ^a	2×TPU ^b	MDC ^c	RER ^d		[RN]	2×TPU ^a	MDC ^b	RER ^c
Location	²⁴¹Am					¹³⁷Cs			
IDN	0.00×10 ⁰	0.00×10 ⁰	2.30×10 ⁻⁴	0.811		5.85×10 ⁻³	7.84×10 ⁻⁴	3.36×10 ⁻⁴	0.324
IDN Dup.	1.20×10 ⁻⁴	1.48×10 ⁻⁴	2.20×10 ⁻⁴			6.22×10 ⁻³	8.29×10 ⁻⁴	3.24×10 ⁻⁴	
TUT	3.05×10 ⁻⁵	1.06×10 ⁻⁴	2.25×10 ⁻⁴	0.492		3.81×10 ⁻³	5.62×10 ⁻⁴	4.44×10 ⁻⁴	1.419
TUT Dup.	6.59×10 ⁻⁵	9.40×10 ⁻⁵	8.92×10 ⁻⁵			2.80×10 ⁻³	4.37×10 ⁻⁴	4.22×10 ⁻⁴	
	⁴⁰K					²³⁴U			
IDN	4.81×10 ⁻¹	6.18×10 ⁻²	6.07×10 ⁻³	0.520		2.33×10 ⁻²	3.89×10 ⁻³	5.40×10 ⁻⁵	0.261
IDN Dup.	5.29×10 ⁻¹	6.85×10 ⁻²	5.18×10 ⁻³			2.19×10 ⁻²	3.69×10 ⁻³	5.55×10 ⁻⁵	
TUT	1.04×10 ⁰	1.34×10 ⁻¹	7.77×10 ⁻³	1.604		2.32×10 ⁻²	3.89×10 ⁻³	6.62×10 ⁻⁵	0.247
TUT Dup.	7.73×10 ⁻¹	9.88×10 ⁻²	6.66×10 ⁻³			2.46×10 ⁻²	4.11×10 ⁻³	1.67×10 ⁻⁴	
	²³⁵U					²³⁸U			
IDN	1.23×10 ⁻³	4.03×10 ⁻⁴	1.81×10 ⁻⁴	0.252		2.30×10 ⁻²	3.85×10 ⁻³	5.37×10 ⁻⁵	0.161
IDN Dup.	1.09×10 ⁻³	3.81×10 ⁻⁴	1.86×10 ⁻⁴			2.39×10 ⁻²	4.03×10 ⁻³	5.55×10 ⁻⁵	
TUT	1.63×10 ⁻³	5.07×10 ⁻⁴	8.18×10 ⁻⁵	0.292		2.53×10 ⁻²	4.18×10 ⁻³	6.59×10 ⁻⁵	0.261
TUT Dup.	1.43×10 ⁻³	4.59×10 ⁻⁴	7.59×10 ⁻⁵			2.69×10 ⁻²	4.48×10 ⁻³	6.14×10 ⁻⁵	

^a [RN] = Radionuclide concentration

^b Total propagated uncertainty

^c Minimum detectable concentration

^d Relative Error Ratio



Figure 4.7 - Sediment Sampling Sites

4.8 Biota

4.8.1 Sample Collection

The concentration of radionuclides in plants is an important factor in estimating the intake of individual radionuclides by humans through ingestion. Therefore, rangeland vegetation samples were collected from the same six locations from where the soil samples were collected (Figure 4.6). The vegetation samples were chopped into 2.5-5-cm (1-2-in)-pieces, mixed together well, air dried at room temperature, and sent to the contract laboratory for analysis. Also collected were muscle tissues from two road-killed deer and one quail, both species commonly consumed by humans. Fish is also consumed in large amounts; therefore, fish samples from PCN, PEC, and BRA (three different locations on the Pecos River) were collected. The muscle tissues from the deer, quail, rabbit, and fish were sent to the laboratory for analysis.

4.8.2 Sample Preparation

Weighed aliquots were taken from the bulk of the chopped vegetation samples and animal tissue samples from each location. The aliquots were transferred into separate containers and dried at 100°C (212°F). Gamma spectrometric determinations of ^{40}K , ^{60}Co , and ^{137}Cs were performed directly from these aliquots. The samples were then dry-ashed, followed by wet-ashing and dissolution in 8M nitric acid. Aliquots from the dissolved samples were taken for the determinations of ^{90}Sr , $^{233+234}\text{U}$, ^{235}U , ^{238}U , ^{238}Pu , $^{239+240}\text{Pu}$, and ^{241}Am .

4.8.3 Results and Discussions

Vegetation

Uranium-234 was detected in all vegetation samples; because of its naturally low concentration, ^{235}U was not detected in any vegetation sample (Table 4.19). Concentrations of ^{234}U ranged from $4.18 \times 10^{-4} \pm 3.34 \times 10^{-4}$ Bq/g ($1.13 \times 10^{-2} \pm 9.03 \times 10^{-3}$ pCi/g) at WSS to $8.21 \times 10^{-4} \pm 2.75 \times 10^{-4}$ Bq/g ($2.22 \times 10^{-2} \pm 7.43 \times 10^{-2}$ pCi/g) at WEE. Uranium-238 was detected all but one sample, WSS and varied between $2.54 \times 10^{-4} \pm 1.32 \times 10^{-4}$ Bq/g ($6.86 \times 10^{-3} \pm 3.57 \times 10^{-3}$ pCi/g) at MLR to $5.03 \times 10^{-4} \pm 2.05 \times 10^{-4}$ Bq/g ($1.36 \times 10^{-2} \pm 5.54 \times 10^{-3}$ pCi/g) at WEE. The concentration of ^{234}U and ^{238}U did not vary significantly between locations (ANOVA, ^{234}U $p = 0.548$, ^{238}U $p = 0.527$). The primary source for uranium in plant tissues is the soil, so this difference from the uranium results for soils may seem counterintuitive. However, uptake of radionuclides and contamination by resuspension are highly species dependent. Because of small-scale differences in soil type, shading, water availability, and other microenvironmental conditions, plants of the same species collected adjacent to one another will often have very different radionuclide concentrations.

Concentrations of ^{238}Pu , $^{239+240}\text{Pu}$, and ^{241}Am were less than the minimum detectable concentrations in every vegetation sample (Table 4.19).

Waste Isolation Pilot Plant 2001 Site Environmental Report
DOE/WIPP 02-2225

Potassium-40 was detected in every vegetation sample (Table 4.19), ranging from $1.64 \times 10^{-1} \pm 2.75 \times 10^{-2}$ Bq/g ($4.43 \times 10^0 \pm 7.43 \times 10^{-1}$ pCi/g) at WEE to $4.29 \times 10^{-1} \pm 6.48 \times 10^{-2}$ Bq/g ($1.16 \times 10^1 \pm 1.75 \times 10^0$ pCi/g) at SMR. The concentration of ^{40}K in vegetation was not significantly different between years (ANOVA, $p = 0.348$). Like uranium, the primary source for potassium in plant tissues is the soil, and this difference from the ^{40}K results for soil is probably due to the same factors. Cesium-137 was not detected in vegetation samples. Cobalt-60 was detected in sample location SEC. Strontium-90 was not detected in any of the vegetation samples.

Table 4.19 - Radionuclide Concentrations (Bq/g Wet Mass) in Vegetation Near the WIPP Site.
See Appendix B for the sampling locations.

Location	[RN] ^a 2×TPU ^b MDC ^c			[RN] 2×TPU MDC			[RN] 2×TPU MDC		
	²⁴¹ Am			²³⁸ Pu			²³⁹ Pu		
MLR	4.48×10^{-5}	7.92×10^{-5}	1.38×10^{-4}	-1.59×10^{-5}	5.51×10^{-5}	1.47×10^{-4}	-1.58×10^{-5}	3.17×10^{-5}	1.17×10^{-4}
SEC	0.00×10^0	0.00×10^0	1.53×10^{-4}	1.31×10^{-5}	6.92×10^{-5}	1.40×10^{-4}	0.00×10^0	0.00×10^0	3.53×10^{-5}
SMR	1.05×10^{-4}	1.12×10^{-4}	1.64×10^{-4}	-6.48×10^{-5}	2.25×10^{-4}	5.99×10^{-4}	0.00×10^0	0.00×10^0	1.75×10^{-4}
WEE	1.49×10^{-5}	6.66×10^{-5}	1.39×10^{-4}	1.43×10^{-5}	6.40×10^{-5}	1.33×10^{-4}	1.43×10^{-5}	2.86×10^{-5}	3.89×10^{-5}
WFF	9.99×10^{-5}	9.77×10^{-5}	1.34×10^{-4}	2.80×10^{-5}	5.62×10^{-5}	1.03×10^{-4}	0.00×10^0	0.00×10^0	1.03×10^{-4}
WSS	3.22×10^{-5}	6.48×10^{-5}	1.19×10^{-4}	4.55×10^{-5}	6.81×10^{-5}	1.11×10^{-4}	0.00×10^0	0.00×10^0	4.11×10^{-5}
Location	²³⁴ U			²³⁵ U			²³⁸ U		
	[RN] 2×TPU MDC			[RN] 2×TPU MDC			[RN] 2×TPU MDC		
MLR	4.66×10^{-4}	1.79×10^{-4}	3.85×10^{-5}	0.00×10^0	0.00×10^0	1.62×10^{-4}	2.54×10^{-4}	1.32×10^{-4}	1.04×10^{-4}
SEC	6.25×10^{-4}	2.78×10^{-4}	1.77×10^{-4}	2.96×10^{-5}	5.96×10^{-5}	8.03×10^{-5}	4.55×10^{-4}	2.24×10^{-4}	6.48×10^{-5}
SMR	7.33×10^{-4}	2.67×10^{-4}	1.32×10^{-4}	6.62×10^{-5}	7.73×10^{-5}	5.99×10^{-5}	4.63×10^{-4}	1.99×10^{-4}	4.85×10^{-5}
WEE	8.21×10^{-4}	2.75×10^{-4}	4.74×10^{-5}	2.15×10^{-5}	7.47×10^{-5}	1.59×10^{-4}	5.03×10^{-4}	2.05×10^{-4}	4.70×10^{-5}
WFF	4.63×10^{-4}	1.84×10^{-4}	4.18×10^{-5}	1.90×10^{-5}	3.81×10^{-5}	5.14×10^{-5}	3.53×10^{-4}	1.58×10^{-4}	4.14×10^{-5}
WSS	4.18×10^{-4}	3.34×10^{-4}	1.62×10^{-4}	0.00×10^0	0.00×10^0	2.00×10^{-4}	4.18×10^{-4}	3.74×10^{-4}	4.40×10^{-4}
Location	¹³⁷ Cs			⁶⁰ Co					
	[RN] 2×TPU MDC			[RN] 2×TPU MDC					
MLR	6.77×10^{-4}	1.15×10^{-3}	1.39×10^{-3}	1.19×10^{-3}	1.54×10^{-3}	1.87×10^{-3}			
SEC	1.18×10^{-3}	2.73×10^{-3}	3.07×10^{-3}	4.44×10^{-3}	2.72×10^{-3}	3.08×10^{-3}			
SMR	6.14×10^{-4}	2.64×10^{-3}	2.96×10^{-3}	1.68×10^{-3}	2.71×10^{-3}	3.01×10^{-3}			
WEE	-2.75×10^{-6}	1.17×10^{-3}	1.37×10^{-3}	3.14×10^{-5}	1.53×10^{-3}	1.78×10^{-3}			
WFF	1.69×10^{-4}	1.18×10^{-3}	1.40×10^{-3}	6.73×10^{-4}	1.59×10^{-3}	1.88×10^{-3}			
WSS	9.66×10^{-4}	1.68×10^{-3}	1.95×10^{-3}	9.73×10^{-4}	1.86×10^{-3}	2.29×10^{-3}			
Location	⁹⁰ Sr			⁴⁰ K					
	[RN] 2×TPU MDC			[RN] 2×TPU MDC					
MLR	3.28×10^{-4}	4.39×10^{-3}	6.60×10^{-3}	2.16E-01	3.53×10^{-2}	1.78×10^{-2}			
SEC	1.94×10^{-3}	4.17×10^{-3}	6.15×10^{-3}	4.18E-01	6.36×10^{-2}	3.05×10^{-2}			
SMR	3.75×10^{-3}	4.11×10^{-3}	5.96×10^{-3}	4.29E-01	6.48×10^{-2}	2.76×10^{-2}			
WEE	-4.23×10^{-4}	4.42×10^{-3}	6.69×10^{-3}	1.64E-01	2.75×10^{-2}	1.36×10^{-2}			
WFF	-5.29×10^{-3}	4.20×10^{-3}	6.67×10^{-3}	2.93E-01	4.55×10^{-2}	1.72×10^{-2}			
WSS	1.47×10^{-3}	4.41×10^{-3}	6.54×10^{-3}	2.56E-01	4.22×10^{-2}	2.00×10^{-2}			

^a [RN] = Radionuclide concentration

^b Total propagated uncertainty

^c Minimum detectable concentration

A duplicate analysis of the vegetation sample from WEE was performed for all the radionuclides of interest (Table 4.20). Concentrations of ^{234}U , ^{238}U , and ^{40}K were above detection limits in the duplicate sample. Relative Error Ratio values exceeded one for ^{234}U , ^{238}U , and ^{40}K , indicating a nonhomogenous sample.

**Waste Isolation Pilot Plant 2001 Site Environmental Report
DOE/WIPP 02-2225**

Animals

Of the radionuclides of interest, ^{234}U , ^{238}U , and ^{40}K were detected in deer, rabbit, and quail tissue (Table 4.21). The mean concentrations did not differ from year 2000. These results can be used only as a gross indication of uptakes, as the sample sizes are too small to provide a robust analysis.

Table 4.20 - Results of Duplicate Vegetation Sample Analysis. Units are Bq/g.
See Appendix B for the sampling locations.

Location	[RN] ^a	2×TPU ^b	MDC ^c	RER ^d				
	^{234}U				[RN]	2×TPU	MDC	RER
WEE	8.21×10^{-4}	2.75×10^{-4}	4.74×10^{-5}	1.839	1.64×10^{-1}	2.75×10^{-2}	1.36×10^{-2}	3.778
WEE Dup.	2.43×10^{-4}	1.52×10^{-4}	1.61×10^{-4}		4.22×10^{-1}	6.25×10^{-2}	1.79×10^{-2}	
Location	^{238}U				^{40}K			
	[RN]	2×TPU	MDC	RER	[RN]	2×TPU	MDC	RER
WEE	5.03×10^{-4}	2.05×10^{-4}	4.70×10^{-5}	1.14				
WEE Dup.	2.25×10^{-4}	1.30×10^{-4}	4.70×10^{-5}					

^a [RN] = Radionuclide concentration

^b Total propagated uncertainty

^c Minimum detectable concentration

^d Relative Error Ratio

Table 4.21 - Radionuclide Concentrations (Bq/g Wet Mass) in Deer and Quail Near the WIPP Site

Sample Type	[RN] ^a	2×TPU ^b	MDC ^c				[RN]	2×TPU	MDC			
	^{241}Am			^{238}Pu			^{239}Pu			^{238}U		
Deer ^d	3.14×10^{-7}	1.42×10^{-6}	1.32×10^{-6}	2.74×10^{-7}	1.04×10^{-6}	1.59×10^{-6}	-2.05×10^{-8}	6.95×10^{-8}	1.56×10^{-6}	7.92×10^{-6}	1.93×10^{-5}	5.49×10^{-7}
Quail ^e	1.23×10^{-6}	3.40×10^{-6}	3.03×10^{-5}	-1.01×10^{-4}	2.79×10^{-4}	2.87×10^{-5}	0.00×10^0	0.00×10^0	8.35×10^{-6}	1.20×10^{-3}	3.32×10^{-3}	2.18×10^{-5}
Rabbit ^f	1.84×10^{-6}	2.13×10^{-6}	1.65×10^{-6}	0.00×10^0	0.00×10^0	1.67×10^{-6}	-6.18×10^{-7}	1.24×10^{-6}	4.55×10^{-6}	3.89×10^{-5}	1.14×10^{-5}	1.60×10^{-6}
Sample Type	^{234}U			^{235}U			^{238}U			^{238}U		
	[RN]	2×TPU	MDC	[RN]	2×TPU	MDC	[RN]	2×TPU	MDC	[RN]	2×TPU	MDC
Deer	1.07×10^{-5}	2.62×10^{-5}	5.51×10^{-7}	1.44×10^{-7}	3.74×10^{-7}	6.80×10^{-7}	7.92×10^{-6}	1.93×10^{-5}	5.49×10^{-7}	7.92×10^{-6}	1.93×10^{-5}	5.49×10^{-7}
Quail	1.07×10^{-3}	2.93×10^{-3}	8.93×10^{-6}	3.69×10^{-5}	1.06×10^{-4}	1.41×10^{-5}	1.20×10^{-3}	3.32×10^{-3}	2.18×10^{-5}	1.20×10^{-3}	3.32×10^{-3}	2.18×10^{-5}
Rabbit	4.81×10^{-5}	1.31×10^{-5}	1.61×10^{-6}	5.11×10^{-6}	3.96×10^{-6}	1.98×10^{-7}	3.89×10^{-5}	1.14×10^{-5}	1.60×10^{-6}	3.89×10^{-5}	1.14×10^{-5}	1.60×10^{-6}
Sample Type	^{137}Cs			^{60}Co			^{40}K			^{40}K		
	[RN]	2×TPU	MDC	[RN]	2×TPU	MDC	[RN]	2×TPU	MDC	[RN]	2×TPU	MDC
Deer	-1.76×10^{-4}	7.60×10^{-4}	3.49×10^{-4}	2.06×10^{-4}	2.43×10^{-4}	3.85×10^{-4}	9.34×10^{-2}	3.85×10^{-2}	3.22×10^{-3}	9.34×10^{-2}	3.85×10^{-2}	3.22×10^{-3}
Quail	2.09×10^{-4}	2.02×10^{-3}	3.95×10^{-3}	1.77×10^{-3}	2.04×10^{-3}	5.16×10^{-3}	1.41×10^{-1}	3.66×10^{-1}	4.23×10^{-2}	1.41×10^{-1}	3.66×10^{-1}	4.23×10^{-2}
Rabbit	-1.59×10^{-4}	5.59×10^{-4}	6.40×10^{-4}	-4.85×10^{-4}	7.70×10^{-4}	8.21×10^{-4}	1.07×10^{-1}	1.74×10^{-2}	9.29×10^{-3}	1.07×10^{-1}	1.74×10^{-2}	9.29×10^{-3}

^a [RN] = Radionuclide concentration

^b Total propagated uncertainty

^c Minimum detectable concentration

^d Mean of three samples collected near WIPP. TPU represents the standard deviation of the mean.

^e Mean of two samples collected near WIPP. TPU represents the standard deviation of the mean.

^f Single Sample

Uranium-234 and ^{238}U were detected in all the fish samples. Uranium-235 was detected in 67 percent of the fish samples (Table 4.22). Neither plutonium or ^{241}Am isotope was detected in fish.

Waste Isolation Pilot Plant 2001 Site Environmental Report
DOE/WIPP 02-2225

Cesium-137, ^{60}Co , and ^{90}Sr were not detected in any of the fish samples (Table 4.22). Potassium-40 was detected in all fish (Table 4.22). It was lowest in the sample from BRA ($5.66 \times 10^{-2} \pm 9.40 \times 10^{-3}$ Bq/g [$1.53 \times 10^0 \pm 2.54 \times 10^{-1}$ pCi/g]), and highest in the sample from PCN ($1.03 \times 10^{-1} \pm 1.55 \times 10^{-2}$ Bq/g [$2.78 \times 10^1 \pm 4.19 \times 10^{-1}$ pCi/g]).

Table 4.22 - Radionuclide Concentrations (Bq/g Wet Mass) in Fish Near the WIPP Site.
See Appendix B for the sampling locations.

Location	[RN] ^a	2×TPU ^b	MDC ^c	[RN]	2×TPU	MDC	[RN]	2×TPU	MDC
	^{241}Am			^{238}Pu			^{239}Pu		
BRA	1.65×10^{-6}	1.93×10^{-6}	1.49×10^{-6}	9.95×10^{-7}	1.42×10^{-6}	1.35×10^{-6}	4.96×10^{-7}	9.99×10^{-7}	1.35×10^{-6}
BRA	1.03×10^{-6}	1.20×10^{-6}	9.29×10^{-7}	1.10×10^{-6}	1.57×10^{-6}	1.49×10^{-6}	0.00×10^0	0.00×10^0	1.49×10^{-6}
PCN	6.48×10^{-7}	1.30×10^{-6}	1.75×10^{-6}	5.96×10^{-7}	1.20×10^{-6}	1.61×10^{-6}	5.92×10^{-7}	1.19×10^{-6}	1.61×10^{-6}
PCN	1.28×10^{-6}	1.82×10^{-6}	1.73×10^{-6}	1.26×10^{-6}	1.47×10^{-6}	1.14×10^{-6}	0.00×10^0	0.00×10^0	3.09×10^{-6}
PEC	7.03×10^{-7}	2.44×10^{-6}	5.18×10^{-6}	3.50×10^{-6}	5.25×10^{-6}	8.58×10^{-6}	0.00×10^0	0.00×10^0	8.58×10^{-6}
PEC	0.00×10^0	0.00×10^0	4.92×10^{-6}	-1.22×10^{-6}	1.74×10^{-6}	5.67×10^{-6}	0.00×10^0	0.00×10^0	4.48×10^{-6}
	^{234}U			^{235}U			^{238}U		
BRA	8.70×10^{-5}	1.68×10^{-5}	8.29×10^{-7}	3.02×10^{-6}	2.18×10^{-6}	1.02×10^{-6}	3.77×10^{-5}	8.92×10^{-6}	8.25×10^{-7}
BRA	5.48×10^{-5}	1.08×10^{-5}	5.88×10^{-7}	1.07×10^{-6}	1.08×10^{-6}	7.25×10^{-7}	3.26×10^{-5}	7.29×10^{-6}	5.85×10^{-7}
PCN	1.03×10^{-4}	2.19×10^{-5}	4.33×10^{-6}	4.00×10^{-6}	3.10×10^{-6}	1.55×10^{-6}	5.37×10^{-5}	1.32×10^{-5}	1.25×10^{-6}
PCN	1.58×10^{-4}	2.99×10^{-5}	9.88×10^{-7}	3.59×10^{-6}	2.60×10^{-6}	1.22×10^{-6}	8.51×10^{-5}	1.79×10^{-5}	2.67×10^{-6}
PEC	1.32×10^{-4}	2.70×10^{-5}	1.65×10^{-6}	2.25×10^{-6}	2.62×10^{-6}	2.04×10^{-6}	6.73×10^{-5}	1.64×10^{-5}	1.64×10^{-6}
PEC	1.96×10^{-4}	3.63×10^{-5}	1.11×10^{-6}	5.07×10^{-6}	3.31×10^{-6}	1.37×10^{-6}	9.62×10^{-5}	2.00×10^{-5}	3.81×10^{-6}
	^{137}Cs			^{60}Co					
BRA	9.99×10^{-5}	6.55×10^{-4}	7.62×10^{-4}	-1.65×10^{-4}	7.33×10^{-4}	7.81×10^{-4}			
BRA	-4.29×10^{-4}	5.33×10^{-4}	5.59×10^{-4}	1.66×10^{-4}	5.00×10^{-4}	5.77×10^{-4}			
PCN	3.92×10^{-4}	1.01×10^{-3}	1.18×10^{-3}	-5.07×10^{-4}	1.13×10^{-3}	1.18×10^{-3}			
PCN	-3.45×10^{-4}	5.44×10^{-4}	5.77×10^{-4}	2.06×10^{-4}	5.25×10^{-4}	6.07×10^{-4}			
PEC	2.37×10^{-3}	1.47×10^{-3}	1.39×10^{-3}	3.89×10^{-5}	1.49×10^{-3}	1.62×10^{-3}			
PEC	2.12×10^{-4}	5.29×10^{-4}	6.03×10^{-4}	-2.85×10^{-4}	6.29×10^{-4}	6.85×10^{-4}			
	^{90}Sr			^{40}K					
BRA	1.45×10^{-5}	9.40×10^{-5}	1.54×10^{-4}	9.51×10^{-2}	1.69×10^{-2}	1.51×10^{-2}			
BRA	3.35×10^{-5}	7.84×10^{-5}	1.26×10^{-4}	5.66×10^{-2}	9.40×10^{-3}	6.29×10^{-3}			
PCN	2.20×10^{-4}	1.69×10^{-4}	2.60×10^{-4}	8.88×10^{-2}	1.98×10^{-2}	2.29×10^{-2}			
PCN	8.55×10^{-5}	7.29×10^{-5}	1.13×10^{-4}	1.03×10^{-1}	1.55×10^{-2}	6.66×10^{-3}			
PEC	7.03×10^{-5}	1.76×10^{-4}	2.83×10^{-4}	9.14×10^{-2}	2.46×10^{-2}	3.18×10^{-2}			
PEC	-2.73×10^{-5}	1.02×10^{-4}	1.70×10^{-4}	8.81×10^{-2}	1.47×10^{-2}	8.62×10^{-3}			

^a [RN] = Radionuclide concentration

^b Total propagated uncertainty

^c Minimum detectable concentration

Neither ^{241}Am nor any plutonium isotopes were detected in fish.

4.9 Summary and Conclusion

The Environmental Monitoring Program collected samples of air particulates, soil, sediment, groundwater, surface water, and biota and analyzed them for radionuclides considered to be indicators of potential contamination from the WIPP facility, as well as other radionuclides of potential interest. Measured concentrations were examined for evidence of WIPP-related contamination, such as higher concentrations of TRU

Waste Isolation Pilot Plant 2001 Site Environmental Report
DOE/WIPP 02-2225

radionuclides after 1998, or higher concentrations in downwind or down gradient directions. Radionuclide concentrations observed were highly variable in space and time and between media. However, no time or space relationships related to WIPP were observed, and concentrations were consistent with background levels. In no case, could environmental concentrations be attributed to WIPP releases. In addition, no events occurred at WIPP, which would lead one to suspect that a release had occurred.

This page intentionally left blank